QUALITATIVE ASSESSMENT OF STRUCTURAL STRENGTH FOR THERMOFORMED HONEYCOMB SANDWICHED STRUCTURES

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ABSTRACTS

Honeycomb sandwiched structures is one of the most valued structural engineering innovations developed by the composites industry. Used extensively in automotive and aerospace technologies, the advanced material construction provides key benefits over conventional metal and structural designs by offering very low weight to power ratio, enhancing structural stiffness, improving durability and cost-effective alternatives. This project involved designing a Thermoforming prototype mould for thermoplastic based honeycomb cores based on industrial general practices. Design consideration includes the sizing of hexagonal cell and low in situ cutting forces. Proprietary polypropylene sheet was thermoformed on wire-cut EDM machined Aluminium (P20) mould. It was found that the 0.006sq.m sandwiched structured fibreglass with 0.001m thickness honeycomb cores stabilized at 0.2MPa compression surface forces.

ABSTRAK

Struktur Sarang Lebah diapit adalah salah satu struktur yang paling bernilai dan berinovasi dalam kejuruteraan struktur yang dibangunkan oleh industri komposit. Digunakan secara meluas dalam teknologi automotif dan aeroangkasa, pembinaan bahan maju menyediakan manfaat utama lebih dari logam konvensional dan reka bentuk struktur dengan menawarkan berat struktur yang sangat rendah kepada nisbah kuasa , meningkatkan kekukuhan struktur , meningkatkan ketahanan dan merupakan alternatif yang kos efektif. Projek ini melibatkan merekabentuk Termopembentukan prototaip acuan untuk termoplastik berasaskan teras sarang lebah berdasarkan amalan umum yang dipraktikkan oleh industri. Pertimbangan reka bentuk termasuklah saiz sel heksagon dan rendah daya pemotongan “in situ”. Lembaran polypropylene akan menjalani proses termopembentukan mengunakan acuan yang telah dimesin mengunakan “wire-cut EDM machine”. Ia telah mendapati bahawa 0.006sq.m yang diapit gentian kaca berstruktur sarang lebah dengan teras ketebalan 0.001m stabil pada 0.2MPa daya permukaan mampatan.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CAD	Computer-aided Design
PP	Polypropylene

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

A mould is a block contained a shape cavity that is filled with a liquid or pliable material like polymer, glass, metal, or ceramic raw materials. The liquid hardens or sets inside the mould, copy its shape. Mould is the other option to a cast. The very common dual-valve moulding process utilized two moulds, one for each half of the object. Piece-moulding uses a number of different moulds, each creating a section of a object with complex geometry. This is usually only used for big and more hi-end objects. In all manufacturing process there are limitations or the ability of the process in moulding known as mouldability.

Plastic moulding is a type of manufacturing process which is the process of shaping plastic using a rigid frame or mould. This technique allows for the creation of objects of all shapes and sizes with highly design flexibility for both simple and huge complex designs. A popular manufacturing option, plastic moulding techniques are use for many car parts, containers, signs and other high volume items. Other than that, there are many plastic moulding processes and techniques, this investigation discusses on the techniques of drape forming.

The study shows that the thermoforming process is widely used to fabricate honeycomb base structure which is a highly valued engineering structure developed by the composites industry. It used extensively in automotive, aerospace and many other industries. The honeycomb sandwich provides the following key advantages over others structures such as light weight, massive stiffness, high durability and production cost savings.

1.2 PROBLEM STATEMENT

The application of advanced thermoforming equipments is widely used in today industries to produces high potential product honeycomb based structure which is not cost affective for a small scale manufacturer and will use up a bigger space to place the machine itself.

As to this, this research is conducted to assess the possibility of producing Honeycomb structure using low cost in-house built Thermoforming equipment.

1.3 OBJECTIVE

The objectives of this project are:

- to design positive thermoforming mould for honeycomb cores.
- to design positive drape thermoforming process for honeycomb foil.
- to evaluate compression test on sandwiched structured composites with honeycomb cores.

1.4 SCOPE OF RESEARCH

This project started by reviewing the product shape and relates it to the type of mould that will be use. The crucial thing in this process is the relation of the mouldability, shapes, process and expected product. After the review several decisions will be made to get the best design to fabricate the positive mould. The decision should be fulfil several factors such that effect several process such as application of the mould during the thermoforming process, process removing the product from the mould after the thermoforming process and force apply during cutting process after thermoforming process. The selected design will be used in CAD software(ANSYS) to generate the mould analysis and the shape achievement to investigate the mouldability of the product. Based from the limitation, some feature will be added to the mould for improvement to ease the production of the product.

CHAPTER 2

LITERATURE REVIEWS

2.1 INTRODUCTION

As a rule, the item shapes direct the state of the mould. Mould can be divided into three types, they are male or positive, female or negative and blended where the mould having both positive and negative attributes.

Parts produce by using male mould have a tendency to have more noteworthy draft angles , heavier base and corner and more slender edges, with within the item repeating the mould surface. Parts produce by using female mould have a tendency to have more modest draft edge, more slender base and corners and significant edges with the outer surface of the item recreating the surface of the moulds.

2.2 THERMOFORMING MOULD

Numerous moulds utilized as a part of thermoforming procedure have normal gathering and working parts. The instrument's pit is intended to structure the yearning last item shape and size focused around the plastic's qualities, for example, degree and bearing of shrinkage. The mould performs two similarly critical capacities particularly for thermoforming methodology. It characterizes one surface of the item and it goes about as heat exchanger to cool the item quickly from initiate temperature to launch temperature. The cooling capacity has an immediate connection in methodology connection on procedure matters in profit making.

The idea ceaseless became additional productive done despite the fact that there might be an issue. The fundamental issue is actually that the heat has to be targeted through one surface area on the product. The insulating space created due to imperfectly close contact between mould and the sheet in use. The cooling rate drastically drop due to this matter and lead to cause defects on the product after the process, for example uneven cooling process with uneven stresses attribute along the plastic. Moderating up the cooling pace will solve the problem, but lead to developing the cost use and resulting growing expenditures.The heat exchange function of the mould brought to an attention. Drape forming is carried out at relatively very low pressure, so moulds can be fabricate from light, cheap and can be machine materials as shown in table 2.1:

TABLE 2.1: Thermal conductivity table

Thermal conductivity-k-W/(m.K)			
Material	Temperature ° Celsius		
	25	125	225
Aluminium	205	215	250
Epoxy Resin	0.35	-	-
Wood	0.45	-	-

Source: Donald V.Rosato(2010)

Simultaneously, to enhance the heat transfer ability of the materials it will include expending expansive expense. The basic material utilized for thermoforming methodology is aluminium because of its properties as well as it’s availability: alternative materials that can be use are, porous sintered metals, cast or sprayed low-melting-point, copper alloys or other form of alloys.

2.3 DESIGNING FOR MOULDABILITY

In designing mould there are some considerations to be taking into calculation to maximize the uniformity of the product shape produce. Based from Dr.Maple Plain study on Photomold(1999-2002) the design requirement are illustrate as follow:

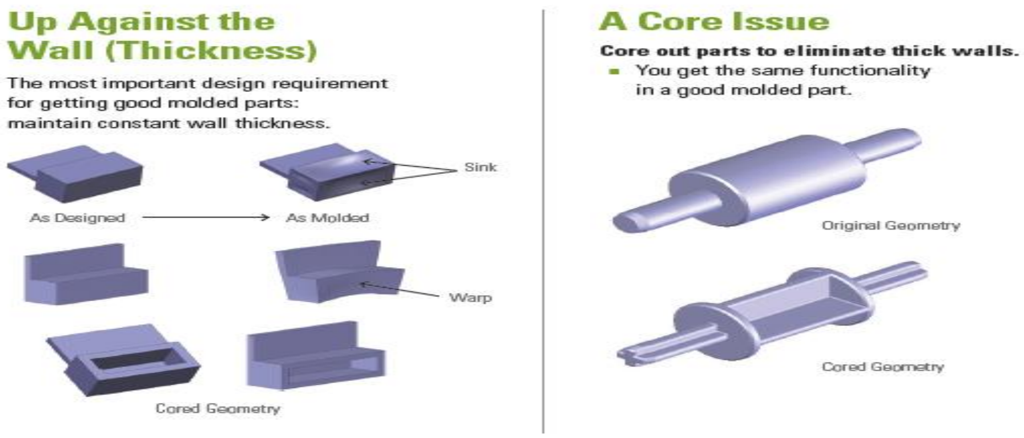


Figure 2.1: Wall thickness and core issue

Source : Dr.Maple Plain study on Photomold(1999-2002)

Let's Get Absolute

Recommended absolute wall thickness by resin.

Resin	Recommended Wall Thickness (Inches)
ABS	0.045–0.140
Acetal	0.030–0.120
Acrylic	0.025–0.150
Liquid crystal polymer	0.030–0.120
Long-fiber reinforced plastics	0.075–1.000
Nylon	0.030–0.115
Polycarbonate	0.040–0.150
Polyester	0.025–0.125
Polyethylene	0.030–0.200
Polyphenylene sulfide	0.020–0.180
Polypropylene	0.025–0.150
Polystyrene	0.035–0.150

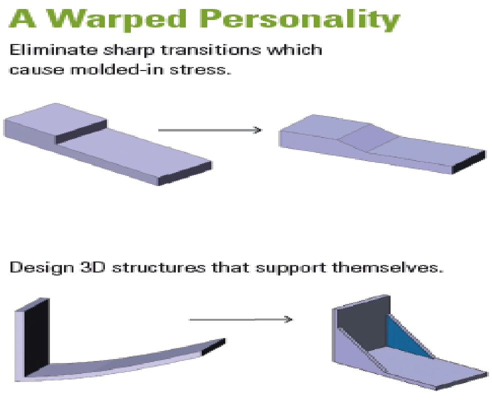


Figure 2.2: Wall thickness and warped personality

Source : Dr.Maple Plain study on Photomold(1999-2002)

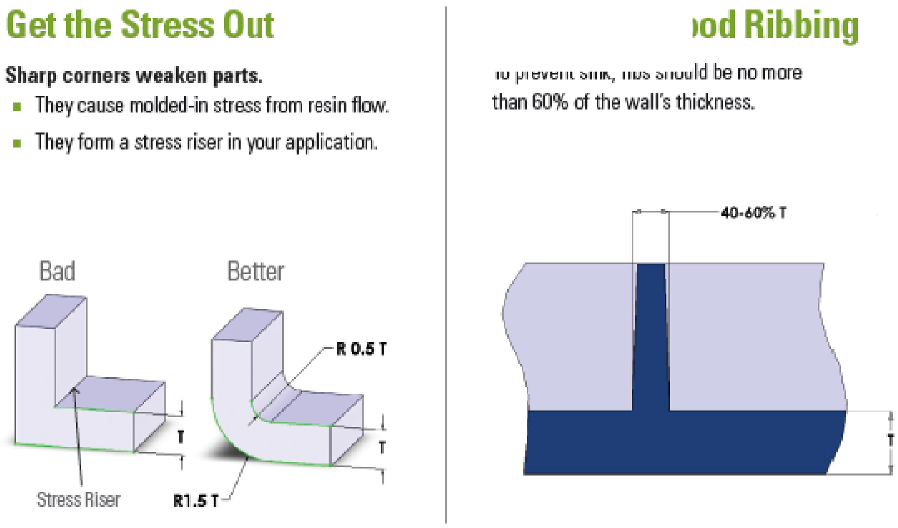


Figure 2.3: Stress and ribbing

Source : Proto Labs (1999-2002)

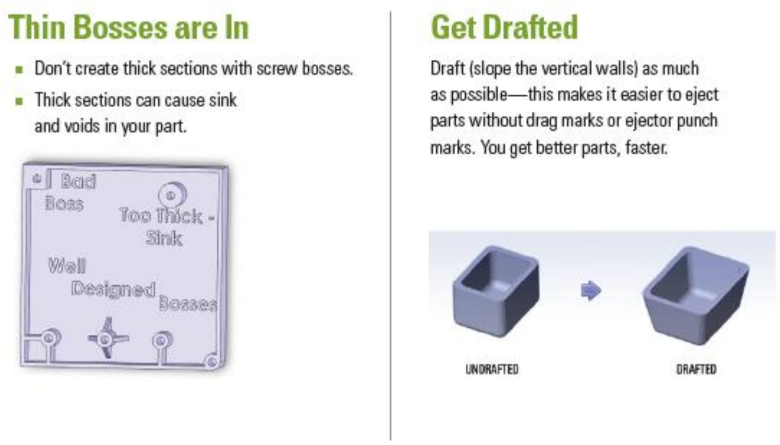


Figure 2.4: Thin bosses and draft angle

Source : Proto Labs (1999-2002)

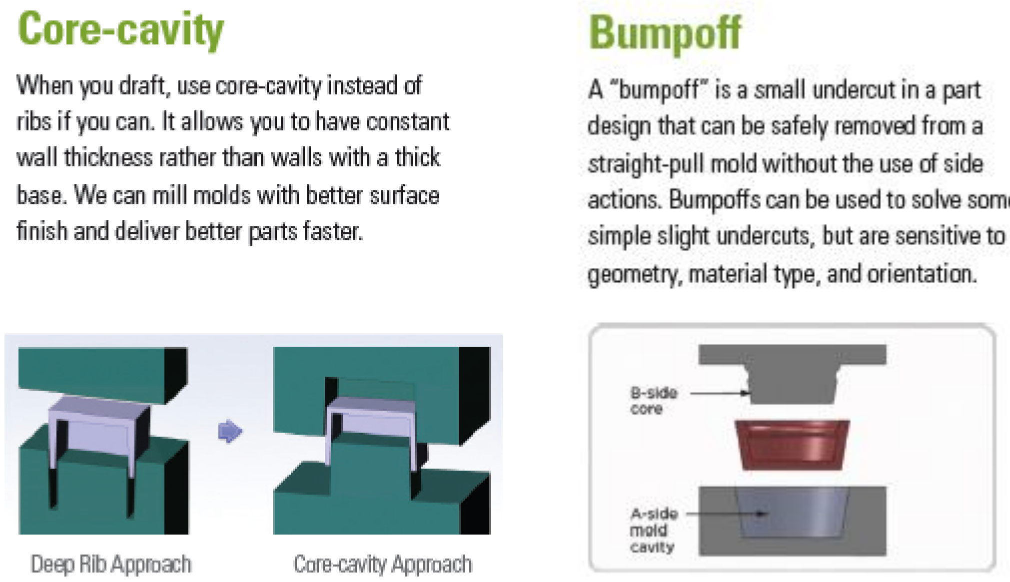


Figure 2.5: Core-cavity and bump off

Source : Proto Labs (1999-2002)

2.4 DESIGN OF MOULD

Based from Materials technology handbook volume 1 by momentum mass media, 2010 there are specific basics facts has to be targeted within the manufacturing regarding moulds. Flat surfaces needs to be avoided if at all, because bit of a domes or maybe dish effect will permit the published to stretch within the entire area. The tendency surface avoided the bit of the bumps that relatively can be found in level section. Maximum permitted vent gap diameters will be different with products and published thickness.

Air evacuation holes ought to be as optimize as possible to reduce restriction of material stream through in-take holes, and the particular opening ought to be back drilled on the surface of the mould. The cavity surfaces ought to be finely sandblasted in order to avoid forming coming from sticking inside the mould and also require several of hover and in-take ports and suppose to be merge along the forming floor and have to be precisely sited throughout ribs, slots, and different features that may very well become isolated since the forming sheet progressively seals over others ports.

The diameter of the port must be small to make sure that small or no mark of their presence is witness on the produce. One method is to make sure the thickness of the forming at the point is thicker than the vent diameter which subject to a diameter not more than 0.3 mm. The vent is released from the opposite larger bore or a series of diminishing bores drilled to about 2mm at the back of the mould. The number of the holes is depends on the desired rate of drawing. Commonly it is desirable to have as fast as possible rate, so the number of holes should be provided based on previous study or experiment.

In Drape forming, they anticipate descending into regular space at the base of the mould. In parts where fine subtle elements or textured examples must be precisely recreated, vent openings short of what 0.5inch (0.013cm) separated are generally fundamental. The female shaped item has the best divider thickness with the most slender bottoms. The converse happens when utilizing the male mould. Amid the shaping the piece of the hot sheet that touches any piece of the mould will begin to cool, bringing about a thicker divider with conceivable solidified hassles.

Size openings ought to be kept as little as could reasonably be expected so they don't meddle with surface necessities. Diverse sorts of plastics have a tendency to have distinctive prerequisite careful placement of the holes will be helpful in providing fast, efficient airflow during forming. Previous studies basically provide guideline for the placement and size of openings. For impact PS up to 0.030inch (0.08cm), opening may be used for material thickness greater than 0.060inch (0.15cm). For thinner sheet, especially where both sides of the part will be view, it may be necessary to reduce hole diameters to 0.010inch (0.03cm) to avoid hole marks.

2.5 VACUUM/DRAPE FORMING

The oldest method of the thermoforming (figure 2.6), it utilizes the sheet’s self-sealing power and evacuation of trapped air through the use of a vacuum. Natural atmospheric force fills the mould cavity, forcing the heated sheet in to the evacuated space. A vacuum pump is necessary in this process. Vacuum forming is the simplest of the thermoforming processes where in my case a positive mould is used in combination with an unencumbered planar upper surface against that's clamped. Detail process is explained in figure 2.7.

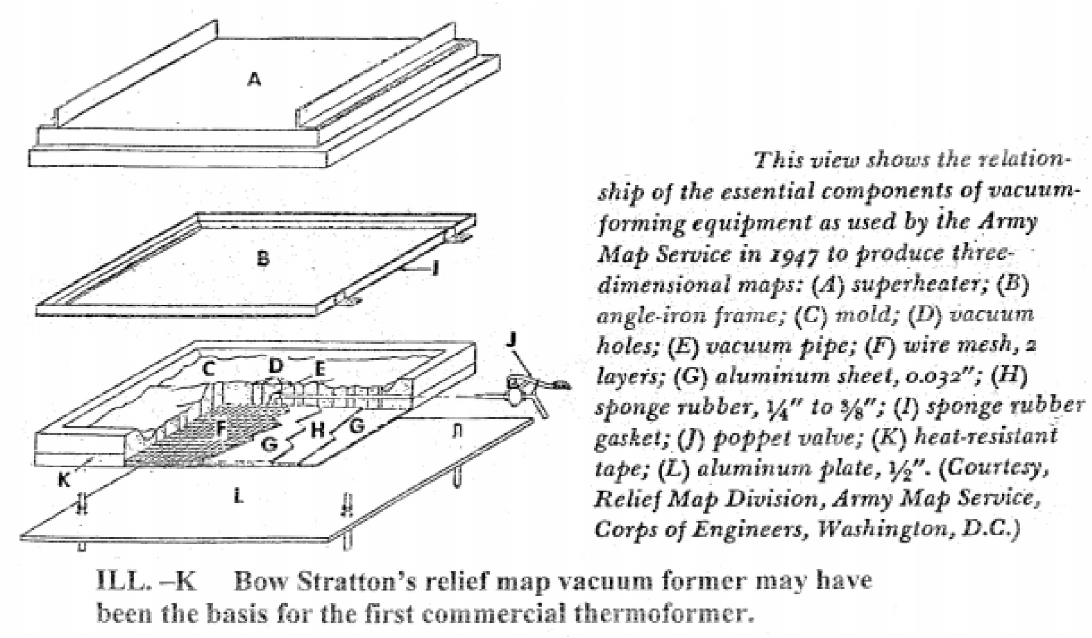


Figure 2.6 : Components used in thermoforming process

Source : (R.Rosen, 1930-1950)

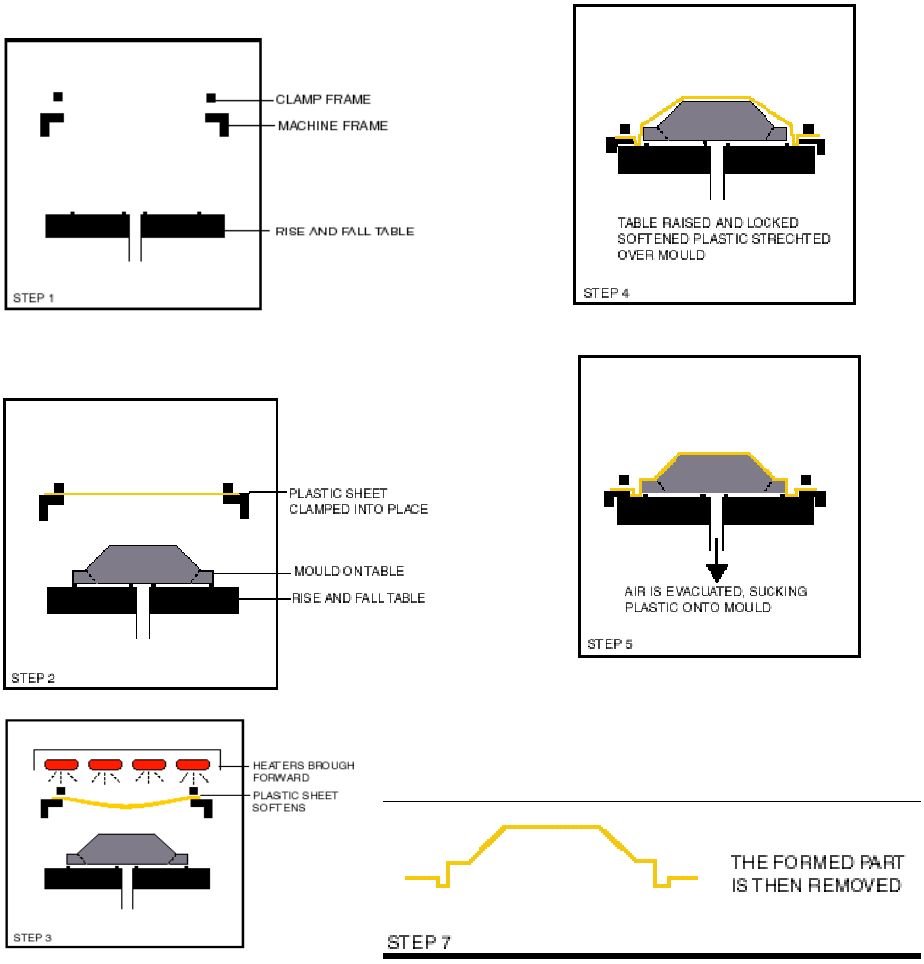


Figure 2.7: Drape forming process

Source : (MULTIFAB INCORPORATED, 2009)

2.6 HONEYCOMB SANDWHICHED STRUCTURES CONSTRUCTION

Honeycomb sandwiched structured is currently leading engineering structures as it offer useful benefits compared to any others structures. It has been commercialize because of its great potential by giving a great structural strength at minimum materials utilization.

The applications of the sandwiched face of the honeycomb structures can be compared with an I-beam, as bending stress were carried to which the beam is subjected. While one of the facing skin is undergoes compression, the other will undergoes tension. Similarly the honeycomb core corresponds to the web of the I-beam. The core withstand the shear loads, enhanced the stiffness of the structure by holding the facing skins apart, and improving on the I-beam, it gives continuous support to the flanges and facing skins to produce a uniformly stiffened panel. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsional and bending rigidity. The comparison of the panel physique as shown in figure 2.8.

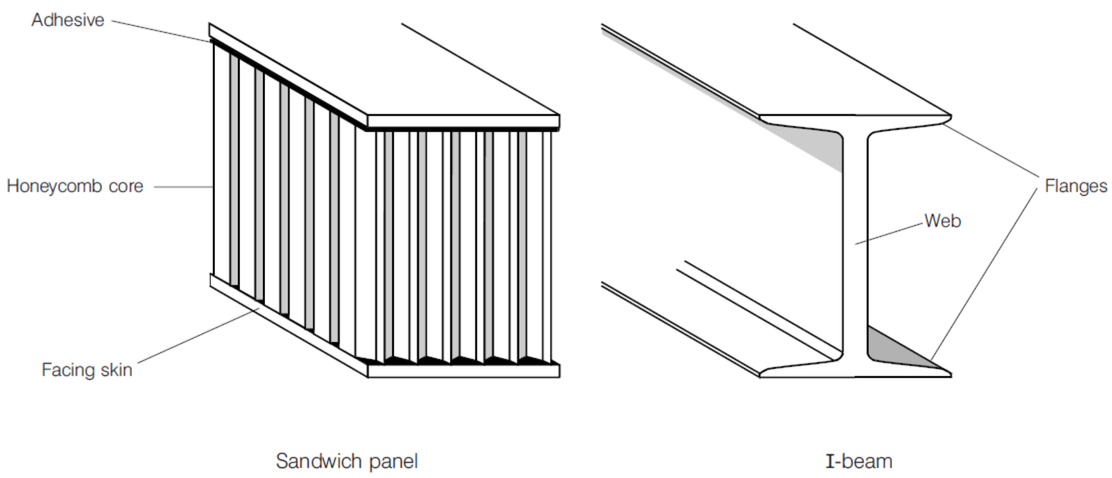


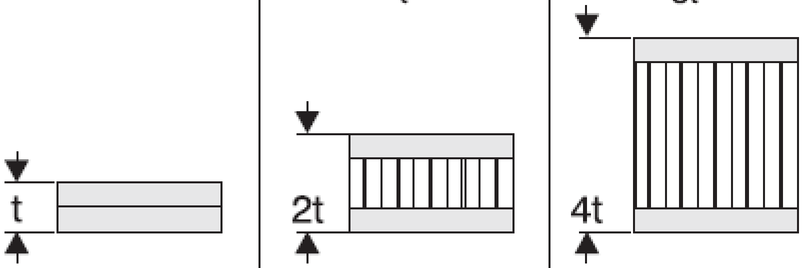
Figure 2.8: Honeycomb panel and I-beam panel

Source : (HEXCELL COMPOSITES, 2000)

Panel with honeycomb cores is said better than solid panel not only because it is cost effective and light in weight but also gives further strength with same weight as the solid panel which can be explained in table 2.2.

Table 2.2: The relative stiffness and weight of sandwich panels compared to solid panels

	Solid Material	Core Thickness t	Core Thickness 3t
Stiffness	1.0	7.0	37.0
Flexural Strength	1.0	3.5	9.2
Weight	1.0	1.03	1.06



Source : (HEXCELL COMPOSITES, 2000)